Effects of Interaural Level and Time Differences on the Externalization of Sound

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652 Eccentric Eye Position Shifts Azimuth Estimates of Interaural Time Differences in the Direction of Ocular Fixation

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Visual space is encoded in eye-centered coordinates, whereas auditory space is encoded in head-centered coordinates. The eyes move frequently during natural behavior, and the spatial maps of these two modalities are dynamically integrated to support navigation and object identification. However, we demonstrated that during *prolonged* changes in eye position, free-field auditory spatial perception shifts in the direction of eye position (by ~40% and with a time constant of ~1 minute). In the present study we examined the effect of eye position on sound lateralization using a range of interaural timing difference (ITD) cues presented using headphones.

In Experiment 1, head-fixed subjects continuously fixated a central or eccentric (±20° left or right) target. After two minutes, localization trials began in which continuous auditory targets (150ms noise bursts [200-1000 Hz], at 5Hz) were presented within an ITD range of ± 450 µs. A joystick-guided laser pointer was aimed at the perceived azimuth associated with the lateral perception of the target. In Experiment 2, the target and pointer modalities were reversed. The joystick now guided an auditory pointer by dynamically adjusting ITD, which subjects aligned with LED visual targets presented in the range ±40° azimuth.

Both experiments demonstrated robust effects of eccentric eye position. Response azimuths for visual pointing to sound targets (ITDs), and for auditory (ITD) pointing to visual targets were biased toward the direction of ocular fixation. Additionally, there was substantial individual variation in the azimuth-ITD gain functions. Many subjects dramatically overestimated the location of auditory cues beyond the predictions of the spherical head model.

These findings extend the previously-reported eye position effect on free-field sound localization to also include headphone presentation of ITD-dependent lateralization. Classic models of neural processing of ITD spatial cues lack a mechanism to explain the dependence on eye position. The influence of eye position on auditory spatial perception is a fundamental property of auditory spatial perception, likely requiring a stage of central processing beyond the initial coding of ITDs.

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653 Minimum Audible Angle in the European Starling (Sturnus Vulgaris)

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Sound localization is not a trivial task for birds having small heads in relation to the wavelength of sounds they use for communication. Theoretical considerations about sound source localization and physical measurements of binaural cues in the auditory system of a songbird, the European starling (Sturnus vulgaris), suggested that in the hearing range of the starling the maximum interaural level differences (ILD) are about 10 dB and the maximum interaural time differences (ITD) are about 100µs (Klump & Larsen 1992). In this psychoacoustic study we investigate the acuity of starling sound localization using operant conditioning techniques to determine the minimum audible angle (MAA).

For measuring the MAA four individuals were trained to detect a switch in azimuth sound source location after being presented with repeated stimuli from a fixed location (reference). The stimuli (overall roving level 63 ±3 dB) were pulses of broadband noise (0.5-6 kHz) or tones (1, 2 or 4 kHz) with a duration of 1000 ms. Additionally, broadband noise and 2-kHz tones with a duration of 100 ms were presented. The azimuth angle used for switching ranged from 11° to 90°. The resulting psychometric functions were analyzed using signal detection theory (threshold criterion d'=1.0).

The starlings' smallest MAA of approximately 18° was measured for broadband noise and 4-kHz tones indicating a best sound localization acuity being comparable to the absolute localization accuracy of other songbirds. The starlings' MAA is improved at the longer stimulus duration and with an increase in frequency from 1 to 4 kHz. Based on the geometry of the head, the MAA at 4 kHz corresponds to an ILD of about 1 dB and an ITD of about 21 µs (Duda & Martens 1998, Kuhn 1977). The probability of detecting the switch increased with an increasing number of repetitions of the reference suggesting that a template of the reference is formed in the starlings' brain that improves with each repetition.

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654 Effects of Interaural Level and Time Differences on the Externalization of Sound

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Distant sound sources in our environment are perceived as externalized and are thus properly localized in both direction and distance. This is due to the acoustic filtering by the head, torso, and external ears, which provides frequency dependent shaping of binaural cues, such as interaural level differences (ILDs) and interaural time differences (ITDs). Further, the binaural cues provided by reverberation in an enclosed space may also contribute to externalization. While these spatial cues are available in their natural form when listening to real-world sound sources, hearing-aid signal processing - such as wide dynamic range compression - affects the ILDs and thereby potentially reduces the perceived degree of externalization. In the present study, the effect of room reverberation on the spectro-temporal behavior of ILDs was investigated. This was done by analyzing speech played at different distances and recorded on a head-and-torso simulator in a standard IEC 268-13 listening room. Next, the effect of ILD fluctuations on the degree of externalization was investigated in a listening experiment

with normal-hearing listeners. The experiment was performed in the same standard listening room and a distant speech source was simulated via headphones using individual binaural impulse responses. The speech signal was then processed such that the naturally occurring ILD fluctuations were compressed. This manipulation reduced the perceived degree of externalization in the listening experiment, which
is consistent with the physical analysis that showed that a decreased distance to the sound source also reduced the fluctuations in ILDs.

655 Absolute and Relative Localization Strategies in Expectation of a Distractor Sound

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A series of studies of horizontal sound localization with a preceding distractor showed that localization responses can be biased away from the distractor location by up to 10°, even on the interleaved baseline trials on which the target was preceded by no distractor [Kopco et al., JASA, 121, 420-432, 2007; Tomoriova et al., ARO Abstract #1019, 2009; Proc. Forum Acusticum 2697-2702; 2011].
Here performance obtained in several experiments was analyzed with the goal of examining whether the observed biases might be related to a change in listener's localization strategy. In the experiments, subjects localized 2-ms frozen noise bursts presented either in the left (-11° to -79°) or the right (11° to 79°) hemifield of the frontal horizontal plane. A distractor preceded the target by 25 to 400 ms on some trials. Distractor's location was fixed throughout a run, either ahead or on the side of the listener, and its frequency of occurrence was parametrically varied.
Since the distractor always came from a known location, the listeners could use it as an anchor for computing a relative position of the following target. Therefore, the observed biases might be a consequence of listeners' switching between an absolute localization strategy, used when no distractor is presented, and a relative strategy, used when the distractor information can be used. To assess this hypothesis, three response measures were analyzed, separately for the responses in the runs with and without the distractors: standard deviations, correlation coefficients, and temporal drifts in response biases. Improvements in some of the measures were observed on the distractor runs. This result suggests that the distractor can provide additional relative information for target localization, and that listeners change their strategies to benefit from this information.
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656 Visual Capture of Auditory Stimuli Differs in Azimuth and Elevation

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When an auditory target is simultaneously presented in close proximity to a spatially well-defined visual target, the perceived location of the sound is typically attracted towards the visual image. This effect, called visual capture, has been extensively studied in azimuth, but has received surprisingly little attention in elevation. Because sound localization in elevation is generally less precise and accurate than in azimuth, we expected that visual capture of auditory targets would be stronger in elevation than in azimuth. However, observations from various experiments in our laboratory (not specifically directed at this question) suggested otherwise.
This experiment re-evaluated visual capture with the specific goal of addressing elevation in comparison with azimuth. Young normal-hearing adults localized broadband noise targets using manual laser pointing, both with and without the presentation of a central visual fixation reference. Visual capture was quantified as the change (with vs. without the visual reference) in mean accuracy and precision (std. dev. of accuracy) of sound localization. Results generally demonstrated robust visual capture in azimuth in the region around the visual reference. Interestingly, visual capture of the same set of targets proved less robust in elevation, with some subjects showing negligible effects despite lower performance in elevation than in azimuth. This finding runs counter to the commonly held notion that visual spatial capture is radially symmetrical, and to earlier cognitive studies of the ventriloquism effect.
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657 Oculomotor Adaptation of Sound Localization Depends Upon the Temporal Relationship Between Targets and Eye Movements

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We previously described a unique oculomotor adaptation by which prolonged changes in eye position shift the perception of auditory space in the same direction as ocular deflection (averaging ~40%, with a mean time constant of ~1 min.). One consequence is that localization of ongoing sounds overshoots target azimuth when the head is fixed but the eyes are free to move during laser pointing. The overshoot is reduced or eliminated when the eyes are fixed. However, this distinction disappears when transient targets are presented, whether or not the eyes are fixed or free to guide localization from memory. A parsimonious explanation is that adaptation is determined by eye position at the time targets are presented. Note that